Fam. 4. **Nephthyadæ.**

Coral arborescent or expanded, fleshy, membranaceous, often very cellular. Cell of the polypes covered externally with large fusiform calcareous spicula.

**Nephthya* (*Spoggodia*). ? *Alcyonidia.* ***Nidalia.* ****Clavularia.*

Fam. 5. **Tubiporidæ.**

Coral calcareous, tubular. Tubes united by transverse plates formed by the expanded edges of the tubes bearing the buds. Polypes cylindrical.

Tubipora.

XLVI.—*On the Arrangement of the Polarizing Microscope in the Examination of Organic Bodies.* By Hugo von Mohl *.

That polarized light is so rarely made use of in the microscopic examination of organic bodies, principally arises from the circumstance that the German and French microscopes, which are almost exclusively used on the Continent, are so badly arranged as to be almost valueless for detecting double refraction in those organic structures which act but feebly upon polarized light. Hence, to mention a few instances, Ehrenberg was unable to detect this property in the leaf-scales of *Olea Europæa,* and in the silicious valves of the Diatomaceæ; nor could Schacht discover double refraction in the primary membrane of the cells of plants; and Pereira, who occupied himself so much with polarized light, was unable to see the black cross in the starch-granules of rice; whilst these structures under my polarizing microscope form most beautiful objects, so that not only can I resolve the lines in *Pleurosigma angulatum* into dots, as well as with common light, but their six-sided form is quite distinct.

Even in my first attempts to use this instrument in phytotomic experiments, I found that a bright and distinct image could be obtained only by exposing the object to very concentrated polarized light. The necessity of this is evident from the fact that three-fourths of the light reflected by the mirror is necessarily lost in its passage through the polarizing apparatus, which loss must be considerably increased by the reflexion taking place at the surfaces of the lenses of the microscope. When, moreover, it is remembered that the depolarizing action of most organic structures is much more feeble than that of inorganic crystals, it may be easily understood that the image of the former is dull and imperfect, or that they remain invisible, if very intense illumination is not applied. Experiment also convinced

* Translated from Poggendorff's Annalen, No. 9. 1859, p. 178.

me that the intensity of the light can hardly be too great; hence I took especial care, in the selection of the apparatus, to ensure obtaining as much light as possible.

For this reason, and to obtain colourless light, I avoided tourmalines or Herapathite, and made use of Nicol's prisms.

In regard to the polarizing apparatus itself, it is advantageous to use, as the polarizer, a Nicol's prism of tolerably large dimensions, through which a broad beam of polarized light may pass to the objects. The illumination of the object, however, is not brighter with a large than with a small Nicol's prism; for when the polarized light, after emerging from the prism, is condensed to a luminous image upon the object by the condenser to be mentioned presently, this is equally bright, whether the prism be large or small; but the size of the image depends upon the size of the transverse section of the Nicol's prism used: hence, when this is too small, observation is rendered difficult by a small portion only of the object, lying in the centre of the field, being illuminated. The Nicol's prism need not, however, be of unusually large dimensions: a diameter of from 10 to 12 lines answers every purpose. As, however, a prism of this size is 2 inches long, care must be taken that there is sufficient room between the mirror and the stage to admit both the prism and the condensers. Hence this space should never be less than 4 inches.

As regards the position of the polarizing Nicol's prism, the question arises whether the relative direction of its oblique terminal faces to the plane of the mirror is a matter of indifference, or whether the horizontal diameter of its rhombic terminal faces should hold a definite position to the horizontal axis of rotation of the mirror. For, when all the lenses are removed from the microscope, on placing a Nicol's prism upon the eye-piece, and turning the mirror to the light, it will be found, on rotating the prism, that the light reflected from the mirror into the microscope is polarized to a considerable extent, and that a marked darkening is produced when the transverse diameter of the rhombic terminal face of the prism is parallel to the horizontal axis of rotation of the mirror, and thus also to the window through which the light proceeds. Hence, when the polarizing prism is fixed in this position under the object, less light will be transmitted to the latter than when the prism is rotated 90° and retained in this position during the observation. This circumstance is in general of no great importance; for with the bright illumination which must be provided under all circumstances, the loss of light caused by a less favourable position of the polarizer is of far less importance in regard to the brightness of the image than might at first be supposed.

Many opticians place the analyzing prism immediately behind the object-glass. This certainly has the advantage of allowing the eye to be placed close to the eye-piece, so that a view of the entire field can be obtained. But this unimportant advantage is counterbalanced by decided objections, and especially by the circumstance that the sharpness of the image is more or less impaired when the light between the object-glass and the eye-piece is allowed to pass through such a massive body as a Nicol's prism, the surfaces of which, moreover, are not usually ground perfectly flat. It is therefore indisputably better to place the prism above the eye-piece, where it much less impairs the beauty of the image. The objection that the field is thus limited is of no importance, as it is easy to find a prism with which this defect does not occur, or merely at the outer margin, which is of little consequence. If the prism is fixed in a tube adapted to the eye-piece, we have, moreover, the advantage that it can be rotated on its axis at pleasure, and may be easily removed and replaced; whilst placing the prism in the tube of the microscope and rotating it within the latter is a complicated arrangement, and involves a waste of time.

Passing to the microscopic apparatus: in the case of this also the greatest possible intensity of light is the first condition of successful results. The most important point is the illuminating apparatus. As regards the mirror, an ordinary plane one may be used; but the best consists of a not too small glass prism, the section of which forms an equilateral triangle. If the surfaces of this are from 15 to 18 lines in length, that is sufficient.

It is essentially necessary that the parallel rays of light, after traversing the Nicol's prism, should be strongly condensed upon the objects. The best apparatus for this is an achromatic condenser consisting of three lenses of about 3 lines focus and large angle of aperture, such as exists in the large English microscopes. Stops are only injurious for the present purpose; but it is evident that the condenser must be capable of being placed in the direction of the axis of the microscope, so that its focus may fall exactly upon the objects. Amici, whose advice I solicited, in case he might improve my arrangements, wrote to me in the negative, considering my apparatus as satisfactory, but suggested that I might substitute a colourless flint-glass plano-convex lens, 5 lines in diameter, and with the convex side downwards, for the achromatic condenser. The result was perfectly satisfactory, especially when ordinary day-light was used, and by no means inferior to that obtained with various achromatic condensers; but when sun-light was used, as described below, this lens was not so good as the achromatic condenser. For the polarizing microscope to yield a good image, the concentration of the light upon the object must be so great, that delicate transparent objects, such as anatomical vegetable preparations, must be almost invisible in the bright light of the field before the analyser is applied; an amount of illumination such as is used in ordinary microscopic observations is totally insufficient; and this is the principal reason why such imperfect results have been obtained by most observers with the polarizing microscope.

With regard to the object-glass, those who have several at hand will do best by using such as transmit most light. For low powers, magnifying about 200 diameters, the better kind of German object-glasses, *e.g.* the Nos. 1 and 2 of Keller's microscope, will answer every purpose; but where higher powers are required, as the $\frac{1}{4}$th, $\frac{1}{8}$th, and $\frac{1}{12}$th, the English glasses are very much the best, especially those made by Ross. The highest object-glasses will of course be used only for the most delicate objects, in which minute details are to be investigated; but, when the illumination is well managed, they transmit sufficient light to allow of the most difficult object being seen distinctly.

Equally important with the arrangement of the polarizing microscope, and the selection of the pieces of apparatus ensuring the greatest intensity of the light, is the choice of the source of the light used for illumination.

When the power required does not exceed 200 or 300 diameters, and when the object exerts considerable polarizing power (as, *e.g.*, the membrane of most vegetable cells, the fibres of spiral vessels, the granules of starch, &c.), common daylight is sufficient; and on many rather dark days in the winter I found no difficulty in making these investigations. A far more favourable result is certainly obtained, on those days when there is full sunshine, by inclining the mirror towards a part of the sky not far from the sun. The light from white cumuli also affords good illumination, except that the constant change of the brightness interrupts observation and fatigues the eyes. These sources of illumination, however, are insufficient in the case of very difficult objects, in which either a very high power is required, or which act but feebly upon the polarized light; thus, to give an instance in a well-known object, on illumination by ordinary daylight I could distinctly recognize the double refraction produced by the silicious carapace of *Pleurosigma angulatum*, but I could not detect the six-sided dots in it. In such cases it requires a far more intense illumination to obtain a bright and sharp image. In regard to this point, all may be accomplished by adopting the arrangement of the solar microscope, the direct light of the sun being received upon a mirror and allowed to fall perpendicularly upon a ground-glass plate fixed in the shutter, the condenser being so arranged that the image of this illuminated glass plate coincides with the object. When low powers are used, this illumination may be too strong, which evil may easily be remedied by altering the position of the condenser; but when the higher powers are used, and the objects are very delicate, the results obtained with it are surprising. It is evident that there is no occasion to darken the room in which the observations are made.

But, as all have not the privilege of occupying a detached house, and the opportunity of making use of sun-light throughout the day, and as we are often without bright sun-light, it would be desirable to find a substitute in strong artificial illumination. Whether this is possible, I do not know. Experiments made with lamp-light did not yield satisfactory results. How far the application of Drummond's light might answer the purpose, I have not experimentally determined. I should, however, have no doubt that good results might be obtained with Drummond's light, since those obtained with lamp-light are by no means to be entirely despised; and the question is not one of the application of light of the highest degree of intensity, as with the solar microscope,—in the case of which, former experiments convinced me that the light produced by the oxy-hydrogen blowpipe and heated lime by no means forms a substitute for sun-light.

I may take this opportunity of making a few remarks upon the use of plates of selenite in observations with the polarizing microscope. When one of these is placed between the polarizer and the object, as is well known (the polarizer and analyzer being crossed), the dark field of the microscope becomes light, and presents one of the colours of Newton's rings, according to the thickness of the plate used. On viewing, under these circumstances, a doubly refracting object lying in the focus of the microscope, this, in a certain relative position to the prisms, appears of a different colour from that of the field, often of great brilliancy, and which passes into the complementary colour, when either the selenite plate or the object is rotated 90°. It is usually stated that the plate of selenite is of important value when the object but slightly polarizes light and therefore cannot be distinguished in the dark field of the microscope, or exhibits merely very obscure indications of radiation of light. In this case, after the insertion of the selenite plate in such manner that the object appears of a different colour from that of the field, and, on the rotation of the plate, passes into the complementary colour, the doubly refracting power of the object is more distinctly evident. Now I will not deny that, in many doubtful instances, this proceeding leads to a decisive result; but it is very frequently unsatisfactory, because the selenite plates are too thick, and thus act very strongly upon the light coming from the polarizer, rendering the field too luminous, and imparting to it too intense a colour. In these cases, the difference between the intense colour of the field and the but slightly differing colour of a very delicate and feebly polarizing object is so difficult to detect, in many instances, that the use of the entire process is very doubtful. On the other hand I cannot too strongly recommend for this purpose the use of very thin plates of mica instead of the selenite. Mica being so tough and readily split, renders it an easy matter to separate such thin laminæ that, when inserted between the polarizer and the object, the field is not coloured, but merely appears more luminous; so that when a very thin plate is used, it becomes dark-grey, and the thicker the plates, the whiter the colour. If a doubly refracting object is then placed under the microscope; according to its position as regards the plate of mica, it becomes more or less brilliantly white, or more or less dark-black. These so strongly contrasted degrees of brilliancy of the object, and their difference from the uniform grey colour of the field, are more easily and distinctly perceptible to the eye than differences of colour; so that in many cases in which, when the selenite plate is used, a doubtful result is obtained, the use of the plate of mica is successful. A satisfactory result, however, is only obtained when the thickness of the plate of mica and its corresponding action upon the polarized light coincide with the intensity of the doubly refracting power of the object. The more feeble the latter, the thinner must be the plate of mica, and the less luminous it must render the field. A series of four or five plates, the thinnest of which brightens the field but little, whilst the thickest produces considerable brightness but no colour, is sufficient for all cases.

In a paper upon the examination of vegetable tissues by the aid of polarized light ('Ann. Nat. Hist.' 1858, vol. i.), I have shown that different vegetable elementary organs, having the same structure but of different chemical composition, are opposed in their action upon polarized light, one exhibiting positive, the other negative colours. To recognize this relation, the diminution of the grey colour of the object produced by the plate of mica, to a more or less deep black, or its augmentation to white, may be used; and the application of the mica plates deserves the preference in all those cases in which the object acts but feebly upon polarized light. In the case of objects, however, which possess this property to a considerable degree, the selenite plates are preferable, because the contrast of the brilliant complementary colours, apparent under these circumstances, is very striking. To produce these colours clearly, a series of selenite plates of increasing thicknesses should also be kept, because, with objects which strongly polarize light, thicker plates are requisite for this purpose. I therefore use plates which render the field of the microscope of a red colour of the first to the fourth order. In the examination of the elementary organs of plants, the red of the 1st and 2nd order was sufficient, and I seldom found it requisite to use the red of the 3rd and 4th order.

These plates are best inserted between the polarizer and the condenser. Hence these pieces of apparatus of the polarizing microscope must be separate and sufficiently apart to allow of the interposition of the plates, which must be capable of rotation horizontally.

It is scarcely necessary to remark that it is best to cement the plates of mica and selenite between two thin glass plates, and to fix them with paste or some such substance in a circular form.

In conclusion, a word upon the preparation of organic bodies for examination under the polarizing microscope.—As is well known, many organic bodies can only be examined microscopically under water; these are prepared for the polarizing microscope in exactly the same manner as for the ordinary microscope. In those objects, however, which may be dried without structural change, as sections of vegetable cellular tissue, starch-granules, &c., it is far better to place them in some more highly refractive liquid than water, as oil of turpentine, or Canada-balsam; the more nearly the refractive power of the organic body and of the preservative liquid agree, the more transparent does the object become, and the more difficult to be distinguished under the ordinary microscope, whilst it yields a so much more beautifully distinct image in the polarizing microscope. Very few structures form an exception to this rule—such as the silicious carapace of the Diatomaceæ after the application of a red heat, which in fact strictly speaking cannot then be considered as organic bodies; these are best examined in the dry state.

BIBLIOGRAPHICAL NOTICE.

Ceylon: an Account of the Island, Physical, Historical, and Topographical; with Notices of its Natural History, Antiquities, and Productions. By Sir James Emerson Tennent, K.G., LL.D., &c. 2 vols. Longman & Co.

The natural history of the island of Ceylon is a subject so extensive and so important, whether regarded in a scientific or in a commercial point of view, that we must hail with pleasure every new contribution to our knowledge of its animal and vegetable productions; while such is its mineral wealth and the importance of its gems, that we are no longer surprised at the early traditions of their splendour and profusion having given rise to fabulous stories of their abundance and